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Atmospheric Chemistry and Physics Discussions

Interactive comment on "A climatological perspective of deep convection penetrating the TTL during the Indian summer monsoon from the AVHRR and MODIS instruments" *by* A. Devasthale and S. Fueglistaler

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Reply to Referee #2

We are very thankful to the referee for her/his careful review and thoughtful suggestions which lead to improvements in the clarity of our manuscript.

The point by point reply to the referee's suggestions is given below.

General comments: 1. In the present study, the brightness temperatures measured from AVHRR on board the NOAA-16 satellite are converted to cloud amounts at sev-

eral different vertical levels using temperature profiles from the AIRS on board the Aqua. This method is not explained clearly and it is a little confusion. What I think is that the AVHRR measured brightness temperature is compared to the temperature vertical profile from the AIRS to get known the level of ice clouds. Please add some descriptions on the method used here. How does this method work? Can you do some validations?

- The referee's interpretation of our method is correct - please see also our reply to similar questions from Referee 1. As pointed out in the manuscript, the presence of deep convection actually increases the brightness temperature at particular pressure level compared to clear-sky condition. Therefore, the estimates provided in our results are on the conservative side (i.e. tend to be low biased in terms of altitude). Since it is impracticable to have collocated both clear-sky and all-sky temperature profiles in time and space, it is rather difficult to directly quantify possible bias due to this assumption. However, it is important to note that this bias is systematic and can be expected to have little effect on the spatial distribution of cloud amount (and its relative variability within the study area), and therefore has negligible impact on the key conclusions of our study. We have made changes in the revised manuscript to clarify these aspects.

2. The level of zero radiative heating (LZRH). The clear sky LZRH is used, but as explained by the authors, the LZRH is strongly affected by cloud. It is better to do a sensitivity study to check how clouds (particularly optical thick cloud which of interest in the present study) affect the LZRH and thereby the corresponding results.

- We fully agree with the reviewer that clouds have an important impact on radiative heating rates, and hence on the position of the LZRH. Most model calculations (to our knowledge) find a net positive (heating) impact of high clouds in the tropics, but the variability (arising from, e.g., solar insolation, cloud particle size and number density, and structure of the cloud field in the column) of the impact on heating rates is very large and the impact can be both positive and negative. Moreover, the cloud effects are highly localized and it is an open question as to how to present this information in an Eulerian (i.e. employing time/area means) frame of reference. As pointed out above in response to the question regarding the effect of the sloping of the LZRH in potential temperature space, addressing these questions properly requires a Lagrangian model study, which is beyond the scope of this paper. The main objective of the paper, namely identification of the spatial distribution of very deep convection, can be reached from the (robust) analysis of the AIRS, AVHRR and MODIS measurements.

Specific comments: 1. Page 2813, line 15. The channel 4 alone is not sensitive to optically thick opaque clouds. Its brightness temperature becomes saturated when optical thickness around 8-10. Maybe you mean that the AVHRR brightness temperature measurements from the channel 4 are used to detect optically thick opaque clouds. Also please give the wavelength of channel 4.

- Indeed, the referee is right. We meant optically thick opaque clouds. The contribution to signal at channel 4 (wavelength 10.5 – 11.5 microns) essentially comes from the top of cloud when the optical thickness is greater than 10. Text in the revised manuscript is correspondingly adjusted.

2. Page 2814, line 2. Give a definition of optically thicker clouds which are studied in the present study.

- The clouds analysed in the present study are opaque ice clouds with optical thickness approximately greater than 10. This information is now added in the revised manuscript.

3. Page 2815, figure 3. Caption of Figure 3. Do you mean "temperature data from AIRS is used to determine occurrence of cloud from AVHRR brightness temperatures"?

- Yes.

4. Page 2818, line 25. When comparing the MODIS cloud fraction for ice cloud with optical thickness larger than 23 to NOAA-16 cloud fraction, please note that MODIS only has cloud optical thickness at the daytime.

- Yes. We have also used only daytime AVHRR observations. This aspect is mentioned in Section 2.2, last line.

5. Page 2819, line15-20. Check these sentences, it seems they are not consistent.

- Corrected.

6. Page 2819, second paragraph. The contexts for Figures 8 and 9 are not clear.

- Figs. 8 and 9 show latitude-height distributions of clouds over the study area from MODIS data. These figures clearly delineate the distributions of all clouds that reach the upper troposphere and most of them preferentially detrain at 200hPa (Fig. 8) and fraction of these clouds that actually penetrate into the TTL (Fig. 9).

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